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Studies on Seed Source Variation in Seed Traits of *Aquilaria malaccensis* (Agar)

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ABSTRACT

Agar scientifically known as *Aquilaria malaccensis* Lamk, belonging to the family Thymelaeceae. The species is included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1994). The species is also listed as 'Vulnerable' globally, 'Critically Endangered' in India (IUCN 2009).It is an economically important native tree species of sub tropical-tropical rainforests of northeast India. Study was carried out in the Department of Forestry during 2015-2017. The aim of this investigation was to measure the variability of seed traits. Field survey was carried out across the population of *Aquilaria malaccensis* throughout Mizoram, Nagaland, Assam, West Bengal and Tripura to select well represented nineteen seed sources viz. Basistha, Ganakpokhari, Hathipara, Hmarveng, Hybergyon, Islam nagar, Kumar ghat, Lanka, Lonigodam, Nagariborline, Naharani, Namti, Nazari, Nelbagan, Newdiakkawan, Rajabhatkhawa, Sephizala, Sukhana and Thahekhu. The trees of approximately same age group were randomly selected and visual assessment viz. tree height, clean bole, good crown spread healthy tree and geographical variation. Collected capsule of each respective seed sources were mixed to make it a composite sample for studying the capsule and seed traits viz. Length of capsule (25.24-32.53 mm), Width of capsule (14.25-18.14 mm), Thickness of capsule (10.73-14.84 mm), Wt. of 100 of capsule (215.67-291.68 g), Length of seed (13.65-16.61 mm), Width of seed (4.42-5.06 mm), No of seeds / capsule, Wt. of 100 seeds (10.35-12.40 g) and moisture content of seed was recorded Significant variations (CD=0.05).

Introduction

Agar scientifically known as *Aquilaria malaccensis* Lamk, belonging to the family Thymelaeceae. The species is included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1994). The species is also listed as 'Vulnerable' globally, 'Critically Endangered' in India (IUCN 2009).It is an economically important native tree species of sub-tropical-tropical rainforests of northeast India. There are 27 *Aquilaria* species distributed worldwide, of which 24 are naturally found in 12 south-east Asian countries i.e. Bangladesh, Bhutan, Cambodia, India, Indonesia, Lao PRD, Malaysia, Myanmar, Philippines, Thailand, Vietnam and

Papua New Guinea (Zich and Compton, 2001). About six species are reported to occur only in Indonesia and two in China (Saikia, 2014). India is the home of three *Aquilaria* species and *Aquilaria malaccensis* is considered endemic to north-east India (Kanjilal et al., 1982). Two species i.e. *A. malaccansis* Lamk. and *A. khasiana* Hall. are found in the evergreen rain forest of north eastern states whereas the third species i.e., *A. macrophylla* Miq. is found in the Nicobar Islands (Giri, 2003). In India, it is mainly confined to the north eastern states and mostly distributed in plains and foot hills of eastern Himalayan states (Chakrabarty *et al*., 2003). Due to high medicinal and perfumery value, the species has great demand in national and international market hence the attempts are now being made to cultivate the species in plantations in India and other places around the world. Currently, the species is mainly surviving in plantations, home gardens and along tea plantations in Assam and its adjoining areas of northeast India and Bangladesh and significantly contributing to the local economy of the region (Saikia, 2014). *Aquilaria* is presently being cultivated on commercial scale mainly in upper Assam region, but even favorable topology, climatic conditions and soil types in Arunachal Pradesh.

Natural resources and astounding biodiversity of India is being slowly depleted by various factors like increasing rate of human and livestock population, hunger, poverty, destitution and famine. Besides these factors, economic growth, modernization and civilization accelerate this problem. However, people are still dependent on the renewable natural biological resources, mainly forests for food, fodder, medicine, household goods and not the least, spiritual and cultural sustenance. Since ancient times, the forest is interwoven with the progress of civilization. Unable to meet their basic needs from agriculture, people are forced to exploit forest not only for fodder and fuel but also to generate cash income through sale of wood and other forest produce. Even if, illegal approach as well as unsustainable harvesting of timber and other produce makes the dwindling of the forest which ultimately leads the widening gap between the demand and supply of needs. This resulted into a situation that per capita forest land at present is only 0.064 ha, down from 0.2 ha in 1951 against the world average 0.64 ha whereas the productivity is 1.34 m^3 per hectare per year against the world's average of 2.1 m^3 per hectare per year (FAO, 2015).

To increase the per capita availability of forest as well as to fulfill the demand, scientists/foresters have given their driven force to increase the productivity of renewable energy source or particularly forest biomass. The biomass productivity rates of different vegetation unit in any region depend on ecological, edaphic and climatic factors with human intervention. The productivity can be increased by using genetically superior genotypes/planting stock along with adoption of intensive silvicultural practices (Zobel, 1977). The relative importance of physiological, genetic and ecological components of the growth and development of forest trees are important from silvicultural point of view (FAO, 1985).

Genetic variation is essential for the long term survival of a species by developing consistency in changed environmental conditions for better adaptability. The amount of genetic variation within a species is a prerequisite for developing effective tree improvement or any breeding programme, which begins with the scanning of available variations in the entire range of species distribution and delimitation of provenance /seed sources capable of providing best adapted trees (Suri, 1984). Patterns of genetic variation reflects responses of species to evolutionary forces operating within environment and can tell how species evolved and may continue to evolve in future. The seeds being the key carrier of the genetic package, when sown to raise the seedlings under a particular environment, express the variability in totality. Therefore seed based parameters are the first essentials of variation studies. Magnitude of genetic variation, spatial distribution of genotype and breeding systems of the population influence and contribute towards genetic composition and quality of the seed collected for tree improvement programme.

Materials and Methods

The present study entitled as "Studies on seed source variation in seed characteristics of *Aquilaria malaccensis* Lamk (Agar)" was carried out to study the pattern of variation in capsule size, seed morphology, moisture content, viability, of *Aquilaria malaccensis* in the experimental field of the Department of Forestry, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal during the year 2015 to 2019.

Seed source is the place from, where the seeds or other propagules materials are collected for the present study purpose. The selection of seed source play an important role because, it determines the physiological potential and the genetic quality of the seeds/other propagules (Zobel and Talbert, 1984).

Selection

Nineteen seed sources representing the considerable geographic variation (latitude, longitude, altitude, climatic and edaphic factor etc.) and the maximum range of distribution of *A. malaccensis* in north-east parts of India covering the states of West Bengal, Assam, Nagaland, Tripura and Mizoram were identified for present study. The geographic range of these sources ranged from 24°19'18.1'' N to 26°05'55.7'' N latitude and 91°47' 40.8' E to 92°45' 30.6' E longitude and altitude varied from 55.3 to 682.7 m asl

Selection of trees

The species generally found in forests and nearby farmers house either in form of plantation or in home gardens which shows large difference in comparison to its natural distribution. The success of seed source research depends on the extent to which selected seed sources represent genetic diversity within natural populations. Therefore, nineteen seed sources where selected for this present study. In selected stands (seed source) of *A. malaccensis*, fresh and mature capsules/fruits were harvested from five phenotypically superior trees, depending upon the availability of the ideotypes (straight and clean boles, insects and disease free healthy tree etc.), which were 100- 300 meter a part to avoid narrowing down the variation in sample due to in breeding (FAO, 1975 and Turnbull, 1975).

Capsules-seed studies

Collection of capsule and extraction of seeds

After observing the physiological maturity stage of capsules (when the capsules turned yellowish green color from green color), fresh mature ripen capsules all parts of earlier selected superior trees were collected in the month of July- August during the year 2015-2016. The capsules of respective seed sources were mixed to make it a composite sample. Then the sample were tagged with proper identity for each seed source and brought to the laboratory in cloth bags to avoid fermentation. Then the morphological parameters of capsules were taken and broken immediately to extract seeds. Then the seeds were sown in the nursery after taking morphological parameters.

Morphological characters of capsules and seed

Hundred randomly selected capsules (5 replicates of 100 capsules of each) from each composite sample of each source were subjected to morphological study. Similarly seed dimensions were measured for 100 randomly selected seeds (5 replicates of 100 undamaged seed each) for each seed source. Observations were recorded with respect to following parameters:

Capsule size (mm)

Capsule length, width and thickness were measured upto decimal point separately for each seed sources with the help of digital caliper (Mitutoyo Absolute).

Capsule weight (g)

Hundred capsules weight of five replicates (each of 100 randomly selected capsules) for each source was recorded up to two decimal points as per ISTA (1996) rules using electrical pan balance.

Seed size (mm)

Seed dimensions viz., length and width were measured up to two decimal points separately for each source with the help of digital calliper to study the seed size variation.

Number of seeds per Capsule

The number of seeds were extracted by breaking the capsules through light hammering and counted manually to keep the record separately for each seed source

Seed weight (g)

Hundred seeds weight of five replicates (each of 100 randomly selected seeds) for each source was recorded up to two decimal points as per ISTA (1996) rules using electrical pan balance.

Seed viability (%)

Seed viability was determined using Tetrazolium (TZ) salt test as prescribed by Kittock and Law (1968).

Seed moisture content (%)

The moisture content was determined as per ISTA rule, 1999. The metal container along with lids was weighted up to four decimal places. Five randomly drawn samples of seed in each seed sources were measured for fresh weight by placing each sample in the metal container.

Then the metal congener along with the lid was weighted again upto four decimal place. Then the metal container was placed in hot air oven at 60^0C for 7 days and re weight until a constant weight had reached with the help of electronic balance. The moisture content was calculated as per the following formula:

Moisture content (%) =

$$\frac{\text{Fresh seed weight} - \text{Dry seed weight}}{\text{Fresh seed weight}} \times 100$$

Results and Discussion

The present investigations on “Studies on seed source variation in seed characteristics of *Aquilaria malaccensis* Lamk (Agar)” were carried out to study the extent of variation between different seed sources.

Capsule and seed traits

Capsule morphology (length, width, thickness and weight)

Data pertaining to the morphological variation of capsule of nineteen seed sources for the year 2015-16; 2016-17 and pooled have been furnished in the table 2, 3 and 4. Wide variation in capsule length, width, thickness and weight were observed among the seed sources. In 2015-16, the capsule length varied from 22.58 mm to 33.05 mm among 19 seed sources. The highest capsule length were recorded in Lonigodam (33.05 mm) which was statistically at par with Hmarveng (32.49 mm) seed source whereas, lowest capsule length were observed in Ganakpokhari (22.58 mm).The seed sources of Hmarveng (32.49 mm), Lanka (31.58 mm) and New Diakkawan (31.24 mm) were statistically at par with each other for capsule length. In the year 2016-17, the length of capsule varied from 26.27 mm to 32.57 mm with an average value of 28.58 mm. Maximum capsule length was recorded in Hmarveng (32.57 mm) followed by New Diakkawan (31.40 mm) whereas, the minimum capsule length was in Kumarghat (26.27 mm) which was statistically at par with Nazari (26.53 mm) and Sephizala (27.07mm) among seed sources. In the pooled analysis, the highest capsule length was noticed in Hmarveng (32.53 mm) followed by New Diakkawan (31.32 mm) whereas, lowest capsule length showed in Ganakpokhari (25.24 mm) which was statistically at par with Kumarghat (25.53 mm). Among all the seed sources, the seed sources of Lonigodam (30.43 mm), Lanka (30.42 mm) and Basistha (30.10 mm), Hybergyon (29.89 mm) and Thahekhu (29.82 mm) were statistically at par with each other.

Similarly, the capsule width varied from 13.94 mm (Rajabhatkhawa) to 18.98 mm (Hmarveng) with a mean value of 15.75 mm in 2015-16. The seed source Hmarveng showed maximum width 18.98 mm followed by New Diakkawn (18.46 mm) and Lanka (18.42 mm) which were statistically at par where as minimum was in Rajabhatkhawa (13.94 mm) which was not significantly differed with Islam Nagar (14.14 mm), Ganakpokhari (14.23 mm) and Nelbagan (14.51 mm). In 2016-17, capsule width ranged from 13.99 mm (Hybergyon) to New Diakkawn (17.81 mm). Highest capsule width was recorded in New Diakkawn (17.81 mm) and lowest width was observed in Hybergyon (13.99 mm) followed by Basistha (14.43 mm), Islam Nagar (14.38 mm), Lonigodam (14.80 mm), Namti (14.37 mm) and Thahekhu (14.59) Lanka (14.33 mm)among the different seed sources. In pooled analysis the maximum capsule width was showed in New Diakkawn (18.14 mm) closely followed by Hmarveng (18.08 mm) where as, minimum was recorded in Islam Nagar (14.25 mm) among the seed sources.

In case of thickness of capsule, the thickness varied from 10.64 mm to 15.00 mm with a mean value of 12.09 mm; 10.29 mm to 14.78 mm with a mean value of 11.60 mm and 10.73 mm to 14.84 mm with a mean value of 11.84 mm in 2015-16, 2016-17 and pooled analysis, respectively. Maximum thickness was recorded in Hmarveng (15.00 mm) followed by New Diakkawn (14.90 mm) where as, both, the seed sources of Islam Nagar and Nelbagan showed the same minimum value (10.64 mm) among the seed sources in 2015-16 . The seed sources of New Diakkawn and Lonigodam recorded the highest (14.78 mm) and lowest (10.29 mm) thickness of capsule in 2016-17. In pooled analysis, New Diakkawn and Islam Nagar registered maximum (14.84 mm) and minimum (10.73 mm) thickness among the nineteen seed sources, respectively.

In case weight of capsules, the weight of 100 capsules varied from 221.50 to 297.67 g with a mean value of 255.45 g; 205.13 to 298.19 g with a mean value of 273.28 g and 215.60 to 295.01 g with a mean value of 264.37 g in 2015-16, 2016-17 and pooled analysis, respectively. Maximum weight of 100 capsules was recorded in Lonigodam (297.67 g) followed by Islam Nagar (295.43 g), Nelbagan (294.55 g) and Rajabhatkhawa (291.47 g) where as, minimum value was recorded in Basistha (221.50 g) followed by Naharani (222.87 g) among the seed sources in 2015-16. The seed sources of New Diakkawn and Lonigodam recorded the highest (298.19 g) and lowest (205.13 g) capsule weight in 2016-17, respectively. In pooled analysis, Nelbagan and Hathipara registered maximum (295.01 g) and minimum (215.60 g) weight of capsules among the nineteen seed sources, respectively. Results of ANOVA showed that the differences among the different seed sources were statistically significant (p=0.05) for all fruit traits in 2015-16, 2016-17 and pooled analysis.

Seed traits (length, width, weight and number of seeds per capsule)

The mean values for various morphological parameters of seed are presented in table 2, 3 and 4 for the year 2015-16, 2016-17 and pooled analysis. The length of seed varied from 13.25 to 16.93 mm with a mean value of 14.80 mm; 14.02 to 16.51 mm with a mean value of 15.03 mm and 13.65 to 16.55 mm with an average value of 14.92 mm in 2015-16, 2016-17 and pooled analysis, respectively. Among the seed sources, maximum length of seed was recorded in New diakkawn (16.93 mm) closely followed by Hmarveng (16.72 mm) whereas, the seed sources of Kumarghat showed the minimum (13.25 mm) followed by Hathipara (13.28 mm) in 2015-16 . The seed sources of Hmarveng and Hathipara recorded the highest (16.51 mm) and lowest (14.02 mm) length of seed in 2016-17. In pooled analysis, Hmarveng (16.61 mm) followed by Newdiakkawn (16.55 mm) registered maximum length of seed and Hathipara (13.65mm) followed by Kumarghat (13.73 mm) showed minimum among the nineteen seed sources, respectively.

Similarly, the width of seed ranged from 4.38 to 5.46 mm with a mean value of 4.84 mm; 4.46 to 5.40 mm with an average of 4.95 mm and 4.42 to 5.17 mm with a mean value of 4.89 mm in 2015-16, 2016-17 and pooled analysis, respectively. Maximum width of seed was recorded in Sephizala (5.46 mm) and lowest was in New Diakkawn (4.38 mm) among the seed sources in 2015-16. highest width of seed was exhibited in Thahekhu (5.40 mm) and lowest was in New Diakkawn (4.46 mm) in 2016-17 where as, Lonigodam (5.14 mm) and Nazari (5.13 mm) were not statistically significant in respect to the seed width. In pooled analysis, maximum seed width was noticed in Sephizala (5.17 mm) and lowest in Newdiakkawn (4.42 mm) among the nineteen seed sources, respectively where as, the seed source of Thahekhu (5.06 mm), Namti and Kumarghat registered the same value (5.05 mm) and Nelbagan (5.04 mm) were not statistically significant for seed width.

On an average, seed weight of 100 seeds ranged from 10.59 to 12.25 g with a mean value of 11.61 g; 10.13 to 12.56 g with a mean value of 11.18 g and 10.35 to 12.40 g with a mean value of 11.39 g in 2015-16, 2016-17 and pooled analysis, respectively. The highest seed weight of 100 seeds was recorded in Rajabhatkhawa (12.25 g, 12.56 g and 12.40 g) and lowest weight was noticed in Islamnagar (10.59 g, 10.13 g and 10.35 g) among the seed sources for the year 2015-16, 2016-17 and in pooled analysis where as, the seed sources of Naharani also registered the same lowest value (10.13 g) in 2016-17.

Generally number of seeds / capsule found one or two but statistically number of seeds / capsule varied from 1.53 to 1.76 with a mean value of 1.67; 1.61 mm to 1.72 mm with a mean value of 1.65 and 1.57 to 1.70 with a mean value of 1.65 among the seed sources in 2015-16, 2016-17 and pooled analysis, respectively. Maximum number of seeds / capsule was recorded in Kumarghat (1.76) which was closely followed by Lanka (1.75) where as, New Diakkawn (1.53) showed the minimum number of seeds (1.53) in 2015-16. During 2016-17, Nagariborline and Basistha registered the highest (1.72) and lowest (1.61) number of seeds / capsule, respectively among the seed sources in 2016-17. In pooled analysis, seed sources of Hathipara and Naharani exhibited the same maximum number of seeds / capsule (1.70) followed by Lanka and Nelbagan showed the same value of 1.69 where as, New Diakkawn showed the minimum (1.57) among the seed sources. As evident from table 2, 3 and 4, the differences for seed parameters were significant (p= 0.05) among all seed sources. The same trend of significant was also observed in the year of study and seed sources.

The data on capsule and seed morphological characters were used for computing the variability estimates. Variability was calculated in terms of range (minimum-maximum), mean, coefficient of variation along with coefficient of phenotypic and genotypic variability for all capsule and seed traits i.e. length, width, weight of capsules and seeds in addition to the thickness of capsules and number of seeds per capsule. Among all these traits, weight of 100 capsules showed widest range (221.50 – 297.67 g; 205.13 – 298.19 g and 215.60 – 295.01 g) in terms of maximum and minimum values followed by the length of capsule in 2015-16, 2016-17 and pooled analysis. Coefficient of variation (CV) was highest in the character of seed width (5.16% and 3.64%) in 2015-16 and pooled analysis, respectively while capsule width exhibited higher (5.28%) coefficient of variation in 2016-17. The weight of 100 capsules and weight of 100 seeds showed similar pattern of least variable among all capsule – seed parameters studied .

It is evident that there was much variation in length, width, thickness, weight of capsules and length, width, weight of seed in addition to the number of seeds per capsule among the different seed sources. The extent of variation in width of seed and capsule was highest. Our findings are well in conformity with the findings of Saikia and Khan (2012) who reported the individual seed weight of 0.126 g, seed diameter 4.66 mm; Roy and Datta (2014) observed the range of fruit length was 2.53 – 2.58 cm, fruit breadth 1.22 – 1.26 cm, fruit diameter 0.48 – 50 cm and seed weight 0.07 – 0.09 g and Soehartono and Newton (2001) recorded the fruit length of 2.20 cm, seed width 1.30 cm, fruit weight 3.17 g and seed weight of 0.03 g in *Aquilaria malaccensis* where as Tabin and Shrivastava (2014) noticed the individual seed weight of 0.782 g which was little higher than the present study.

Variation in capsule and seed morphological characters between the seed sources of *Aquilaria malaccensis* because of the wide adoptability of this species over a wide range of rainfall, temperature and edaphic conditions. Also it might be due to the resource availability during phonological development. The difference in capsule and seed trait can be clearly attributed to the difference in size of capsule resulting from the different rate of the development of leathery exocarp. Similar types of results are reported by Dey (2011) in fruits of gammar; Hanamashetti (1997) and Divakar (2008) in fruits of tamarind. This might be due to different environment at different geographic regions of each seed source and seasonal variables (Murali, 1997). Though the capsule/seeds are collected from different locations of same age approximately but the differences observed in capsule and seed traits might be due to their genetic make up in nature as a result of adaption to diverse environmental conditions throughout their range of distribution (Mathur *et al*., 1984). Besides the age, vigour, crown structure and genotype of mother plant, the locality factors of seed origin are important factors affecting seed traits (Salazar and Quesada, 1987). Such variations in relation to the habitat have also been reported by Gera *et al* (2000) in *Dalbergia sissoo* Wang *et al*., (1998) in *Pinus bungeana* (1998). Significant difference in seed weight may provide a scope for selection of suitable genotypes for initiating improvement of this important tree species and also to select superior seed sources.

Fig.1 Morphology characters of capsules and seeds of different seed sources *Aquilaria malaccensis*for the year 2015 – 16

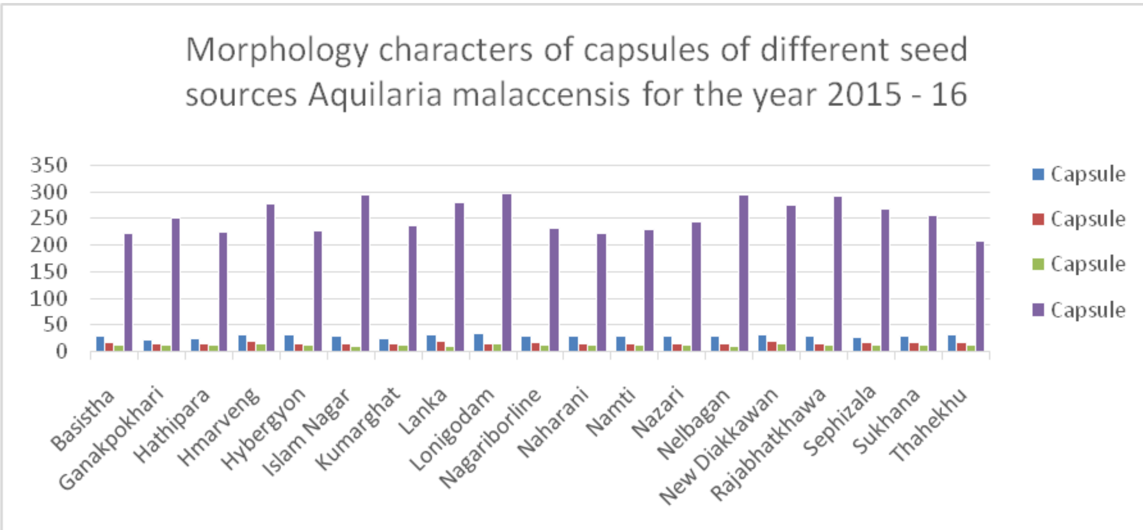

Fig.2

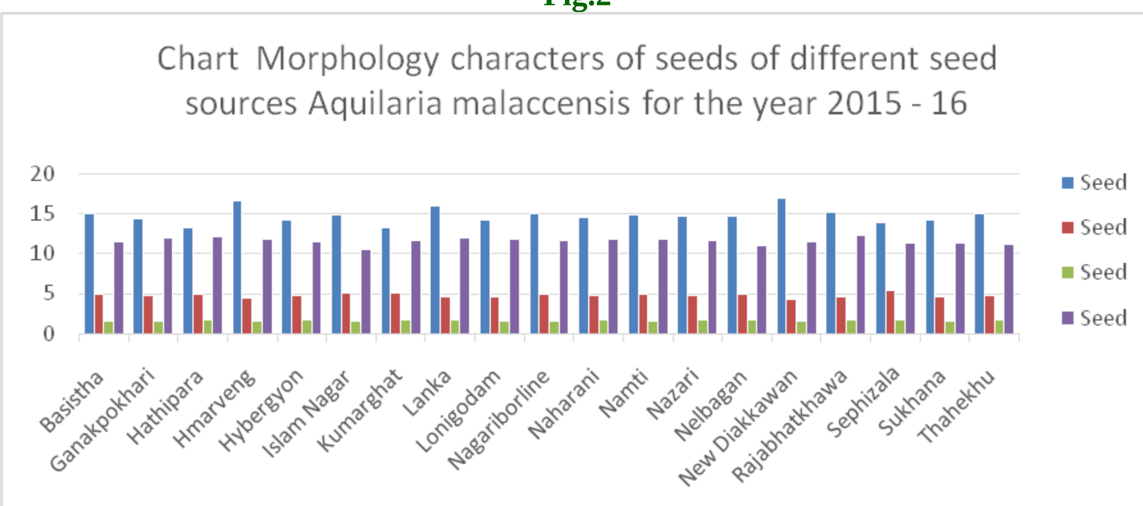

Fig.3 Morphology characters of capsules and seeds of different seed sources *Aquilariam alaccensis* for the year 2016 – 17

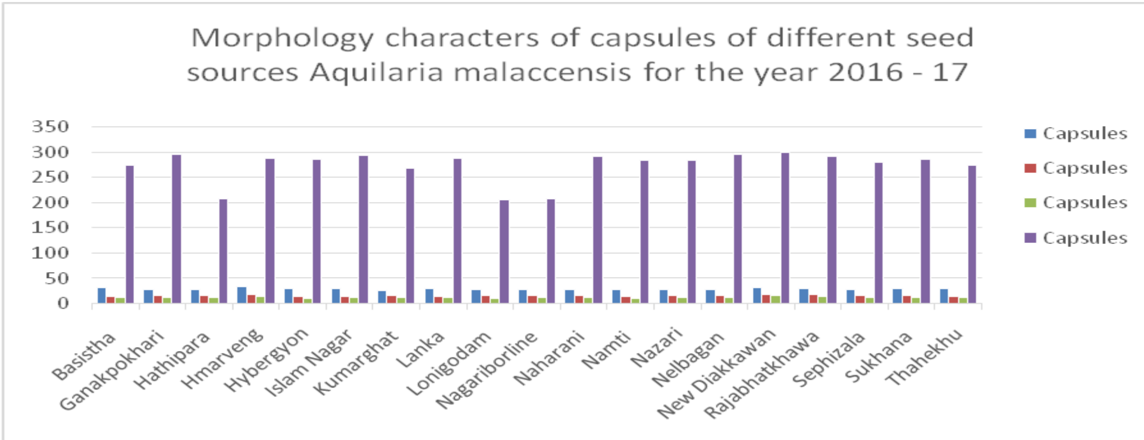

Fig.4

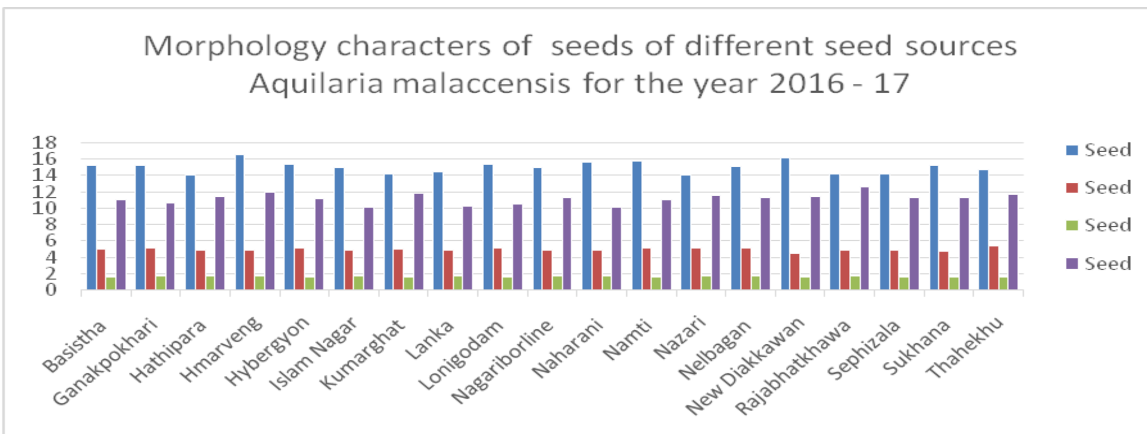

Fig.5. Average (pooled) morphology characters of capsules and seeds of different seed sources *Aquilaria malaccensis*

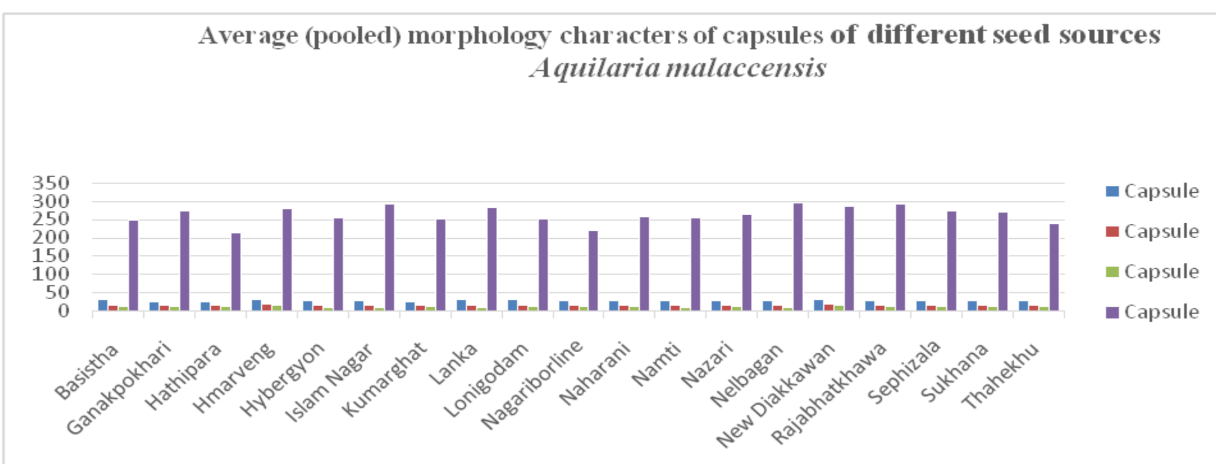

Fig.6

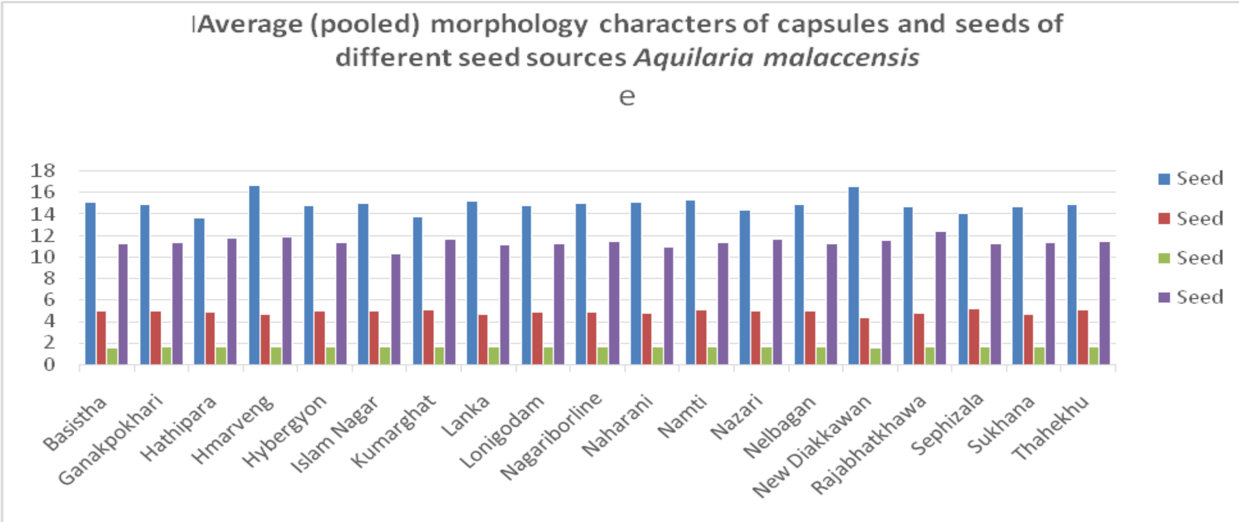

Fig 7 Moisture and viability of seed

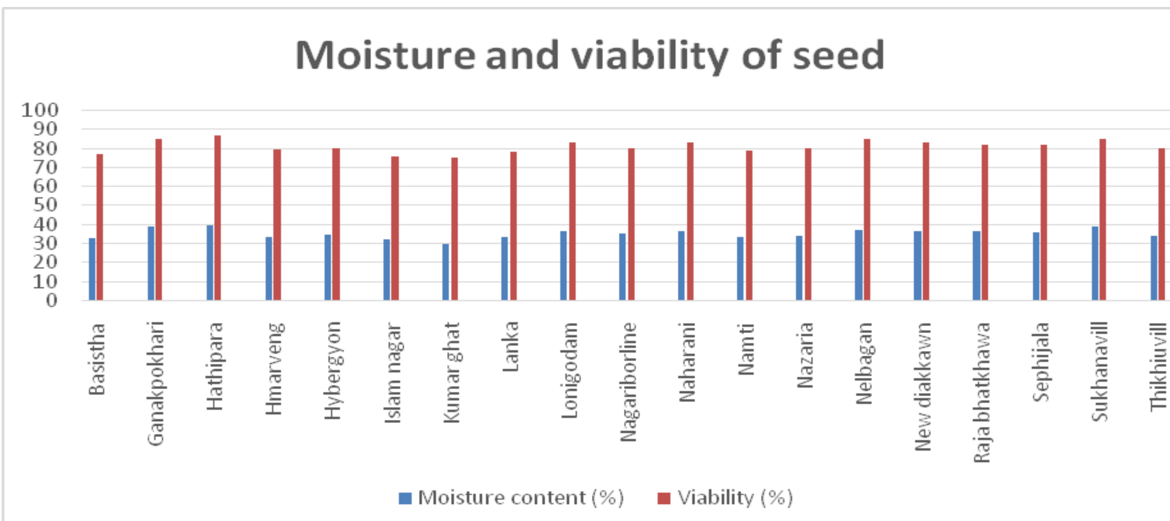

Table 1

	Capsules				Seed			
	Length (mm)	**Width (mm)**	**Thickness (mm)**	**Weight (g/100 capsule)**	**Length (mm)**	**Width (mm)**	**No of seeds / capsule**	**Weight (g/100 seed)**
Mean	**28.93**	**15.75**	**12.09**	**255.45**	**14.80**	**4.84**	**1.67**	**11.61**
CV (%)	3.54	3.614	3.731	2.462	3.598	5.156	4.152	4.09
S.Em (+)	*0.458*	*0.257*	*0.202*	*2.811*	*0.238*	*0.112*	*0.031*	*0.213*
CD (p=0.05)	**1.292**	**0.729**	**0.569**	**7.922**	**0.670**	**0.315**	**0.087**	**0.599**

Table.2

	Capsules				**Seed**			
	Length (mm)	**Width (mm)**	**Thickness (mm)**	**Weight (g/100 capsule)**	**Length (mm)**	**Width (mm)**	**No of seeds / capsule**	**Weight (g/100 seed)**
Mean	**28.58**	**15.35**	**11.60**	**273.28**	**15.03**	**4.95**	**1.65**	**11.18**
CV (%)	3.384	5.281	5.165	3.731	3.404	4.745	4.665	3.185
S.Em (+)	*0.406*	*0.363*	*0.268*	*4.558*	*0.229*	*0.105*	*0.034*	*0.158*
CD (p=0.05)	**1.147**	**1.021**	**0.754**	**12.841**	**0.643**	**0.296**	**0.097**	**0.446**

Table.3

	Capsule				**Seed**			
Seed Source	**Length (mm)**	**Width (mm)**	**Thickness (mm)**	**Weight (g/100 capsule)**	**Length (mm)**	**Width (mm)**	**No of seeds / capsule**	**Weight (g/100 seed)**
Mean	**28.75**	**15.55**	**11.84**	**264.37**	**14.92**	**4.89**	**1.65**	**11.39**
CV (%)	2.394	2.955	3.045	2.204	2.561	3.64	2.89	2.62
S.Em (+)	*0.307*	*0.206*	*0.163*	*2.604*	*0.167*	*0.080*	*0.022*	*0.133*
CD (p=0.05)	**0.866**	**0.578**	**0..457**	**7.341**	**0.470**	**0.225**	**0.061**	**0.377**

Table.4

Mean	**35.32**	**80.81 (64.40)**
CV (%)	7.25	4.75
S.Em (+)	*1.477*	*1.7588*
CD (p=0.05)	**4.238**	**5.045**

Table.5 Genotypic and phenotypic coefficient correlation between capsule and seed characters of *Aquilaria malaccensis*

Character		**Width of capsule (mm)**	**Thickness of capsule (mm)**	**Weight of capsule (g)**	**Length of seed (mm)**	**Width of seed (mm)**	**No. of seed / capsule**	**Weight of seed (g)**
Length of capsule (mm)	G	0.528	0.481	0.308	0.804*	-0.644	-0.470	0.005
	P	0.486	0.451	0.266	0.697	-0.433	-0.241	0.011
Width of capsule (mm)	G		0.904*	0.218	0.650.	-0.754*	-0.502	0.415
	P		0.793*	0.192	0.548	-0.510	-0.211	0.281
Thickness of capsule (mm)	G			0.133	0.613	-0.640	-0.755*	0.421
	P			0.101	0.558	-0.377	-0.382	0.297
Weight of capsule (g)	G				0.411	-0.325	0.028	-0.156
	P				0.339	-0.200	0.020	-0.093
Length of Seed (mm)	G					-0.758*	-0.655	-0.019
	P					-0.475	-0.300	-0.115
Width of seed (mm)	G						0.504	-0.192
	P						0.104	-0.187
No. of seed / capsule	G							0.007
	P							-0.081

Table.6 Mean, range, coefficient of variation, PCV, GCV, heritability (h2), genetic advance and genetic gain for capsule and seed characters of *Aquilaria malaccensis*

Characters	Mean	Range	CV (%)	PCV (%)	GCV (%)	h^2 (%)	Genetic advance	Genetic gain (%)
Length of capsule	28.75	25.24 - 32.53	2.39	6.95	6.53	88.17	3.63	12.63
Width of capsule	15.55	14.25 - 18.14	2.95	7.24	6.62	83.44	1.94	12.45
Thickness of capsule	11.84	10.73 - 14.84	3.06	9.89	9.40	90.43	2.18	18.42
Weight of capsule	264.37	215.67 - 291.68	2.20	9.15	8.67	89.91	44.62	16.94
Length of seed	14.91	13.65 - 16.61	2.56	5.48	4.88	79.22	1.33	8.94
Width of seed	4.89	4.42 - 5.06	3.64	4.89	3.26	44.51	0.22	4.48
No of seeds / capsule	1.65	1.57 - 1.70	2.89	3.29	1.57	22.85	0.04	1.55
Weight of seed	11.39	10.35 - 12.40	2.62	4.33	3.44	63.28	0.64	5.64

Percentage of seed viability and moisture content

As seen from figure 3, the seed viability varied from 75.00 to 86.33%. Among the various seed sources Hathipara showed the highest (86.33%) seed viability followed by Ganak Pokhari (85.00%) and the seed sources of Kumarghat showed the lowest viability (75.00%). Though variation in seed viability was occurred but the value was not statistically significant from one another. Figure 3 reveals that Moisture content of seed ranged between 29.87 to 39.58% with an average value of 35.32%. Among the various seed sources, maximum (39.58 %) moisture content was noticed in Hathipara, which was closely followed by GanakPokhari (39.05%); SukhanaVill (38.96%); Nelbagan (37.33%); LoniGodam (36.81%); Naharani (36.76%); New Diakkawn (36.71%); Rajabhatkhawa (36.37%); Sepaijhala (36.09%) and Nagari borline (35.53%) while the minimum (29.87%) was recorded in Kumarghat which was not differ statistically with the seed sources of Islam Nagar (32.03%); Basistha (32.83); Lanka (33.26%); Namti (33.29%) and Hmarveng (33.38%). It was observed that the moisture content of seed influenced the viability percentage. The variation in viability may be due to the moisture content of the seed. This finding is well agreement with the findings of Roberts (1973) who highlighted the variation in moisture content of seed and altitude of seed source may be attributed to the environmental effects before, during and immediately after harvesting of seeds. Studies conducted by Dey (2011) in *Gmelina arborea* lend support to the present findings. Such variations in relation the moisture content have also been reported in *Aquilaria malaccensis* by Adelina (2004) and Tabin and Shrivastava (2014) as it might be due to the fleshy covering of fruits which provide moisture to the seeds for their survival and maintain the viability.

Genetic studies in capsule and seed traits

The results pertaining to estimate the genetic parameters such as broad sense heritability, genetic advance (at 5% selection intensity) and genetic gain is depicted in table 5. The higher estimates of heritability (90.43%) coupled with moderate genetic gain (18.42%) were recorded in thickness of capsule closely followed by weight of capsule (89.91% and 16.94%). The genetic advance (at 5%

selection intensity) was maximum in weight of capsule (44.62) followed by length of capsule (3.63). Among the seed traits, seed length showed higher estimates of heritability (79.22%) accompanied by low genetic gain (8.94%). Table 5 revealed that phenotypic coefficient of variation (PCV) was little more than genotypic coefficient of variation (GCV). The thickness of capsule exhibited highest phenotypic and genotypic coefficient of variation (9.89%and 9.40%) followed by weight of capsule (9.15% and 8.67%) where as all other capsule – seed traits showed lower phenotypic and genotypic coefficient of variation. The lowest phenotypic and genotypic coefficient of variation was observed in the number of seeds per capsule (3.29% and 1.57%).

Genotypic and phenotypic correlations between character pairs were calculated and are presented in table 6. It revealed that the genotypic estimates were higher than phenotypic ones, indicating an inherent association between the characters. Few character pairs showed significant and positive correlations where as other pairs exhibited negative correlations. The width of capsule was positively and significantly correlated with thickness of capsule. Positive and significant genotypic coefficient of correlation was observed between the length of capsule and length of seed character where as negative but significant genotypic coefficient of correlation was observed between the width of capsule and width of seed (G = -0.754); length of seed with width of seed (G = -0.758) and thickness of capsule with number of seeds per capsule (G = -0.755) character. The highest and positive association (G = 0.904 and P = 0.793) was exhibited between width of capsule and thickness of capsule. In the present study, phenotypic coefficient of variation (PCV) was little more than genotypic coefficient of variation indicating that the environment is influencing the expression of these traits. Estimates of broad sense of heritability were found over 80% for al capsule traits but it was higher in seed length (79.22%) and seed weight (63.28%). However, high heritability coupled with moderate genetic gain and genetic advance were exhibited in capsule weight over thickness of capsule indicating high heritability and moderate genetic gain. This signifies the fact that the capsule weight character is under strong genetic control and contain god amount of heritable additive genetic component which can be exploited further selection and improvement of this species. Therefore, capsule weight can be considered a meaningful character over thickness of capsule for seed source selection. Other capsule-seed traits also showed high heritability in capsule length and width of capsule and moderate heritability in seed length and seed weight but exhibited low genetic gain indicating that these traits are explained by high environmental components of variance. Studies conducted by Uniyal *et al.,* (2002) in *Grewia optiva*; Devagiri *et al.,* (2004) in *Dalbergia sissoo and Dhanai et al.,* (2003) in *Albiziachinensis*lend support to the present findings.

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